The COSMOS Building Design Tool

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Zusammenfassung

Dieser Beitrag beschreibt die Entwicklung einer Methode, wie man bereits am Anfang des Entwurfsprozesses, spezialistische Kenntnis über verschiedene Aspekte des Entwurfs ins Blickfeld der Entwerfenden bringen kann. Das System ermöglicht es einem Studenten oder Architekten in einem frühen Stadium des Entwurfs sowohl die gestalterische als auch die physikalische Aspekte der Probleme zu betrachten. Wir konzentrieren uns in diesem Stück auf den Gebrauch einer graphischen Interface, die es ermöglicht, relativ einfach und mit für einen Entwerfenden bekannten Handlungsweise, explizite Kenntnis zu sammeln über die technischen und ökonomische Folgen einer Projektes und Änderungen in einem zyklischen Vorgehen zu berücksichtigen.

Von Anfang an war es wichtig ein Werkzeug für die Entwerfenden zu entwickeln, das es ermöglicht die Geometrie eines Projektes zu definieren und gleichzeitig systematisch ein Database für die Kalkulation und die Evaluierung darzustellen. Um dieses zu ermöglichen, wurde das Computer Programm COSMOS entwickelt, dessen Eingabe aus der Elementar-Geometrie von dem Projekt zusammen mit funktionellen und physischen Eigenschaften besteht.

Auf Grund dieser Unterlagen werden die intern wichtigen und nach externen Programmen exportierten Daten produziert. Wahrend eines zyklischen Prozesses kann man das Projekt an dem oder genauer spezifizieren in Zusammenarbeit mit das für AutoCAD entwickelte Anwendung Programm DAAC. Mit einem Link zu dem Programm ELAN ist es moglich, die wärmephysikalische Aspekte des Projektes zu kalkulieren.

Abstract

This paper describes the development of a method to bring expert knowledge forward in the preliminary stage of the design process. We are focusing on the use of a graphic interface which makes it possible, in an easy and for a designer, familiar way, to state explicitly about the technical and economical impact of his design proposals. The first problem to overcome was to provide the designer with a design tool that combines the capability to reflect the geometry of the design and at the same time generate systematically, for computing and evaluation, a usable database. To fulfil this task we developed the program COSMOS, it receives the basic geometry of a design and produces a set of data which can be partly evaluated inside the program and furthermore function for design and computation in specialized program. In this paper COSMOS is presented as the design tool developed so far and which we are now are introducing and testing in the education of building design and building physics at our faculty.

Introduction

To solve architectural design problems it is a well known fact that one generally can make a distinction between two types of design attitudes. Designers mainly interested in architecture will attack the design problem at first hand by considering the appearance of a building in terms of space and form. Other more functional or technical oriented designers usually attack the problem in a more rational way by emphasizing the physical appearance of the building design. In the architectural education and practice for the proper management of the design process, it is a difficult task to show the complexity and interaction between what we indicate here as: the geometry or form on the one hand and the functional or technical properties of a building design on the other hand.

This paper is about this particular problem, that is the type of problem, that arises when the question is asked "Whatis the outcome of a building design?" To answer this question. especially in the early stages of the design process, the authors of this paper developed the computer program COSMOS [Hacfoort and Veldhuisen,19911 which has the ability to act as a building design and evaluation tool. In education and practice design skills and technical knowledge are not always integrated and linked together as they should be. In many aspects there is a tendency to deal with building form and building physics in a separate way. In education this may follow a parallelroute, with separate courses in the teaching of design skills and applied physics. In practice, however this is a sequential process, initially by discussing and solving the problems related to the shape of space and solids, texture and colour and subsequently handing over the design to specialists in the various fields of building technology to work out the physical problems and details. To overcome part of this problem, in education as well as in practice, we look for integration of design skills and expertise of building physics.

Our contribution to this, the computer program COSMOS, can act for a number of subjects related to the building design process as a design and evaluation system. In the following, the facilities of COSMOS will be demonstrated by means of a design example HOUSE 1, as shown in fig. 1 and 2.

The COSMOS approach

Making a building design that has to fulfil a specific function involves a hierarchy of detail in the problem-solving process. If the design is in its early stages, it may he called 'preliminary design'. The presented

his pay-off contribution to the design.

In the large scale overview at the beginning, the design process is more open for original and larger payoff contributions, than in case of detailed design, where too many constraints decrease creative solutions considerably. Second, it is more instructive in the preliminary stage to understand the interaction between building form and performance in terms of a set of explicit properties.

To correspond with design practice, the COSMOS program, is based on the creation of a geometrical building concept by means of graphical input. This design concept is automatically connected to a database which gives the drawing a substance according to a defined function and construction. To ensure flexibility of the system there is freedom and control by the user over the building form and the basic materials of which it is made.

If we try to characterize the COSMOS approach, one may call it a 'glass-box method'. We try to control design in an open, unautomated cycle of decision making and problem solving, but most of all by trying to achieve a situation of conscience about the design process as such. In our opinion this will accelerate insight into design problems and make them more easily understood.

With COSMOS we focus on a systematic design method which emphasizes the structural moment in the design process. Our aim is to develop an efficient means by which to master the complexity of the building design process and which easily accessible by designers. For this reason COSMOS and all of the linked programs are developed on the Personal Computer level, hence they are in general easy to use.
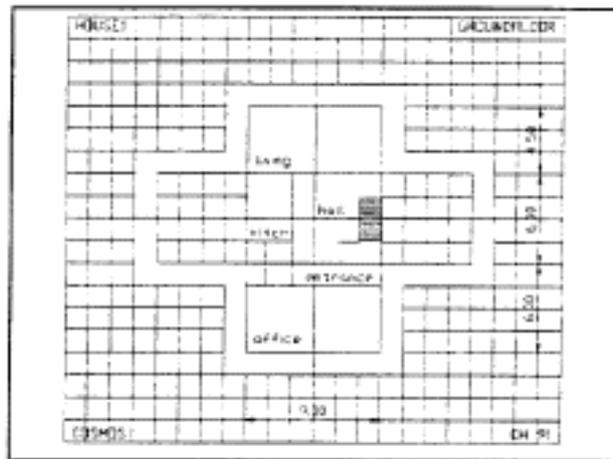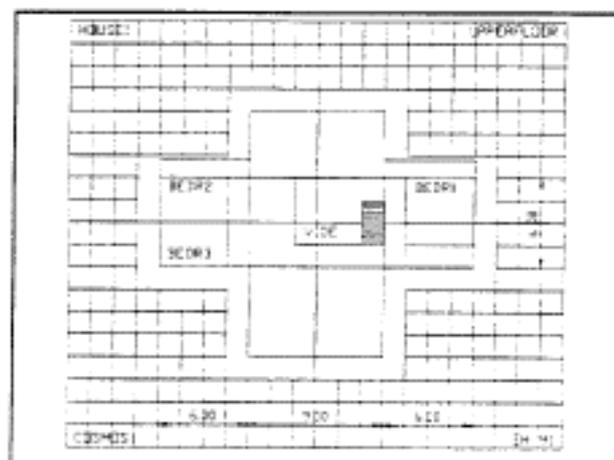

Fig.1 Example: groundfloor

Fig.2 Example: upperfloor

The COSMOS program

The COSMOS program provides the user with a set of facilities to develop a design idea. It is possible to input a basic design and simultaneously evaluate this design on a set of aspects in a cyclic order. COSMOS may he used in three possible ways:

- To input the basic geometry of a design idea, and refine this design by constant evaluation by bringing in more detail.

- To develop a set of alternatives for a basic design showing explicitly the mutual difference of the solutions by comparing the properties.

- To look for properties which have an important impact on the proposed design.

The design is conceptualized as being a hierarchy of spatial units going from building blocks down to specific spaces. During the design process a number of attributes will be increasingly defined for each spatial unit. One of the main attributes is the spatial unit's function. For example, the regime for energy and lighting conditions is determined by the function of each spatial unit. Another set of attributes determines what materials are necessary for the construction of the spatial units. In principle, only modules of the type section, roof, and space are defined:

- Sections are defined by (a combination of) the volume of a box, a prism, or a cylinder.

- Roof sections are specified by a set of predefined common roof shapes.

- Spaces are defined by dividing the zones into several parts.

Evaluation, may he done on two levels of expertise, within inside the COSMOS program quickly on a set of design properties and outside of COSMOS by linking specialized programs. It is therefore possible to develop a design in a continuous process by the use of COSMOS, integrated with more detailed and specialized programs using COSMOS generated data. So all of the preliminary design and evaluation can be done at PC level, with complicated computations completed more effectively at main frame (VAX) level by the use of linked programs, like ELAN for example.

Defining a building design with COSMOS is a straight forward process which can he described in five major steps:

- Define the building type (of which eleven are predefined).

- Define a construction type (of which five are predefined).

- Define the building materials of the major construction elements (which are predefined in relation with the construction type, but can be changed at will by the user).

- Compose the geometry of the building with spatial units (sections) which are always representing a function attached to the building type. An evaluation of the design can be carried out after every input of a spatial unit (section) at will of the user.

- Give the building a geographical orientation.

At every stage of the design it is possible to produce output in the form of files in DXF format, which can

be transferred to and imported in the drafting program AutoCAD. A set of three DXF files is produced to accommodate the production of:

- Isometric or perspective views of the design.

- To plot a cut-out of the design to make a paper model.

- Detailed floor plans, to export back again to COSMOS starling a new evaluation session.

- Detailed drafts with aid of an architectural library.

COSMOS is operational to a great extend and functions at the moment in our faculty in so called mixed courses about 'energy conscientious design'. Some of the students and staff participating on these projects belong to the 'architectural design' group while others belong to the 'building physics' group of the faculty. Building form and building technique oriented attitudes meet each other in mixed groups using COSMOS to make the performance of there designs more explicit. So far the result of this 'mixed education approach', working with this relatively easy to operate and understandable software is positive. On the other hand, these exercises are very helpful to give feed back to improve and extend the software by showing ways on how to implement it in the building design process.
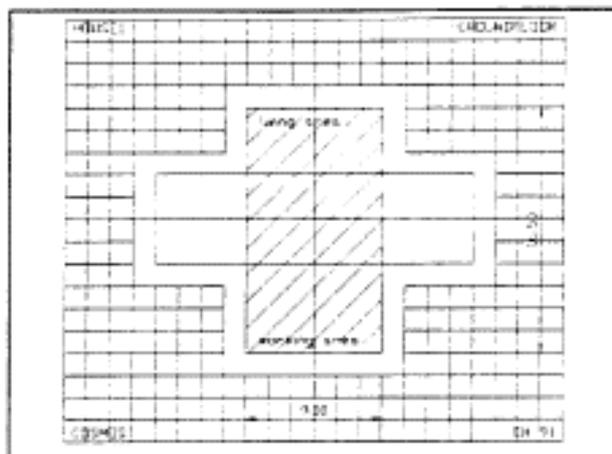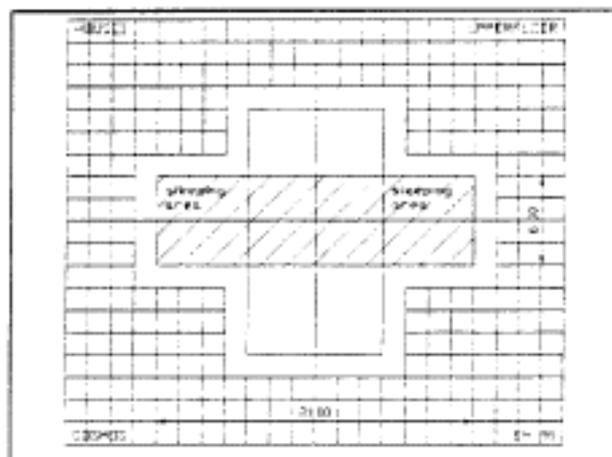

Fig.3 Sketch: groundfloor
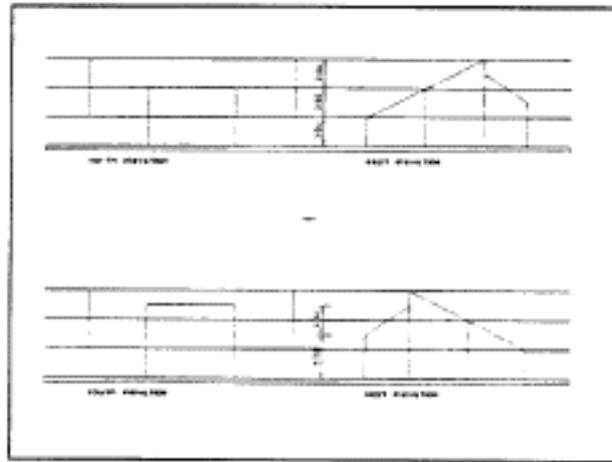

Fig.4 Sketch: upperfloor

Fig.5 Sketch: elevations

A COSMOS exercise

To describe the operation of COSMOS we follow the processing of a small design, example HOUSE I. This is a design proposal for a private house with an attached small private office for a profession like an auditor. This example can be seen in fig. 1 and 2.

At the begin of COSMOS it is presumed that the user has some idea about the concept of his design proposal and there is a thumb sketch of the geometrical concept at hand to start with. COSMOS works on three levels of spatial design, which are the building block, the sections and in a more final stage the spaces, eventually grouped in zones. Thinking of a building in terms of a structure composed of spatial elements connected with the function they have to fulfill is an important aspect in preparing the input.

For the introduced example we have to accommodate three main functions which are: 1) living, 2) sleeping and 3) working space. The concept of the spatial layout consist of.. 1) a groundfloor over the north-south axis 2) an upperfloor over the east-west axis. The inner core of this layout interweaves the floorplans and it functions as the central communication area. This idea as shown in the sketches of fig.3, 4 and *5,* is the starting-point of the exercise to follow. These basic two dimensional sketches contain all the necessary information of the plan to explore for some properties of this concept. To develop this idea and eventually study some alternatives the user can enter the program in this early stage of awareness and step by step bring in more detail. COSMOS will supply the user with supplementary questions about the building construction and material applications.

The COSMOS program consists of three main parts:

      (1) Input of the building properties such as: function, construction and material.

      (2) Plotting the building as a composition of sections (the basic spatial unit).

      (3) Computation and evaluation of the input and producing output for the linked programs.

Part (l):

Next we step trough COSMOS to show in summary the procedures involved. After entering the program with a unique project name the control menu is shown. After starting the program the menu concerning the building function is presented. There are 11 predefined functions as shown in the menu, fig.7. The building type primarily defines the function of all the projected sections of the design. Whenever the designer prefer not to specify a particular function for all of the sections or only for some of them, this serves as a default.

```
BUILDING TYPE:               FUNCTION SECTION:
< 1> house                   < 1> house
< 2> school                  _____
< 3> hospital                < 2> living sct
< 4> sport accom.            < 3> sleeping sct
< 5> cafe/rest.r.
< 6> hotel                   _____
< 7> store                   < 4> entrance
< 8> museum                  < 5> living
< 9> office                  < 6> bedroom
<10> industr.bld.            < 7> kitchen
<11> warehouse               < 8> storage
                             < 9> bathroom
                             <10> toilet Option ? < 1>
                             <11> service
                             <12> horz.circ.
                             <13> vert.circ.
                             <14> unheated
                             <15> roofsection
                             Option ? < 1>
```

Fig.7 Building function menu   Fig.8 Section function menu

Later on the program gives the user a more detailed function list according to this example for a house as shown in the menu fig.8. This menu is based on the in the building type menu selected option <l> of fig.7, and makes it possible to differentiate the function of the sections within the main function of a building block. In this case we choose the function house as the building type, so this brings up the opportunity to define more specific functions of a house, like the living and sleeping function relating to the sections of the example. As we can see in fig.9 the desired construction type can be selected from a list of 5 predefined building construction methods. This selection is related to a database which is defines the quality, quantity and price of construction, materials and labour in general. At the end of part(l) there is the opportunity to redefine the materials of the main building parts according to the selected construction type. In this example the materials conform with the (Dutch) traditional building type (option <l> of fig.9) as shown in fig. 10. According to the users wish it is possible to change the materials within the range set by the program, or define new materials and add them to the existing set. This option gives the freedom to define the materials of any specific construction principle.

CONSTRUCTION: BUILDING MATERIALS:

\<l\> brickwork	< 1 > outerwall	brick+limestone
<2> concrete	< 2 > separationwall	concrete+ lime stone
<3> prefab panel	< 3 > innerwall	limestone
<4> heavy frame	< 4 > groundfloor	joisting
<5> light frame	< 5 > upperfloor	joisting < 6> roofeonstruction
pantile Option ? < l>	< 7> glass	solarbel-silver

Choose other existing material ? <n> ?

Fig.9 Construction type menu Fig. 10 Material type menu

Part (2):

The defining of the geometry is really done in this part, by means of a composition made of volume primitives like a box, a prism or a cylinder. The input is always a section (dimensioned space unit) of a building block which represents a function. The outer envelope exists of panels which consist by default of the defined building material, glass type and glazing percentage. These properties of the section panels can he changed at the request of the user, one by one. Hence it is possible to give the envelope of each section the desired properties such that the user can make a composition of sections representing the intended design (fig. 11). Furthermore there is a set of predefined roof sections to define a roofplan to complete the shape of the plan. During the plotting cycle the user will encounter a couple of options to control and influence this task, among other things, the ability to have an overview of the design so far (fig. 12) and to change it.
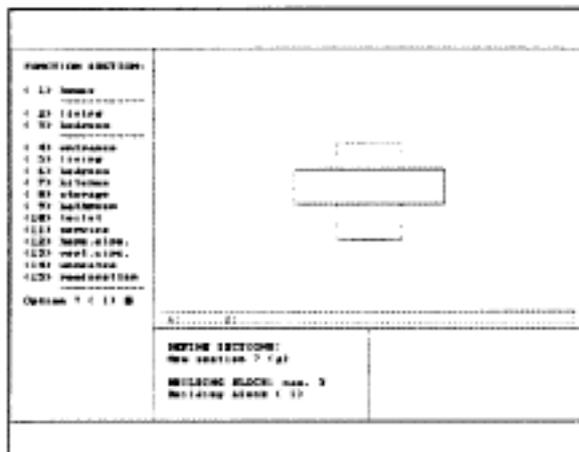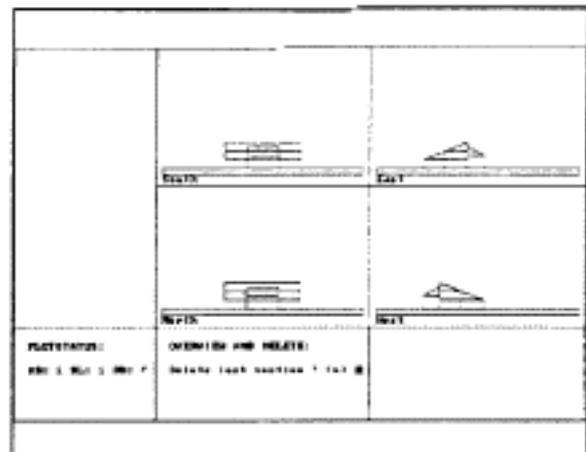

Fig. 11 COSMOS: plot of design

Fig. 12 COSMOS: elevations of design

Part (3):

At the end of the plotting job a database is built, which makes an internal evaluation of the plotted design possible, and parts of it may be exported to linked programs. The evaluation is presented on two screens as shown in fig. 13 and 14. It is only possible in this brief space we mention the basics of this internal evaluation. For a more comprehensive explanation the reader is reader referred to the paper which describes this matter in more detail [Veldhuisen and Hacfoort, 1991],

In the menu at the end of COSMOS (fig. 15) using option 6, the user is able to return to part(2). Here it is possible to adjust the geometry of the design or input the properties of the sections, in a cyclic order. Moreover at the end of part(3) the user can adjust the geographical orientation of the design, allowing alternatives in situation to be generated and studied.
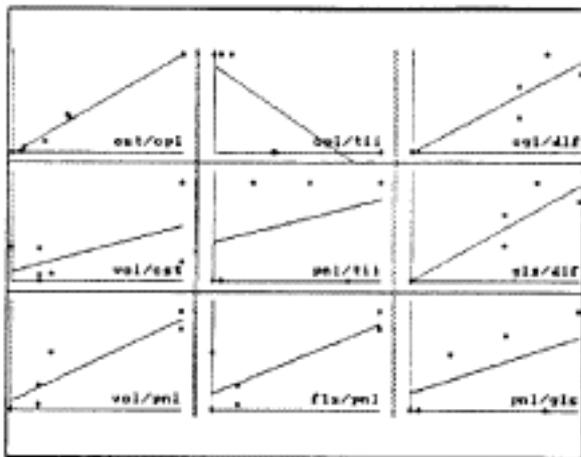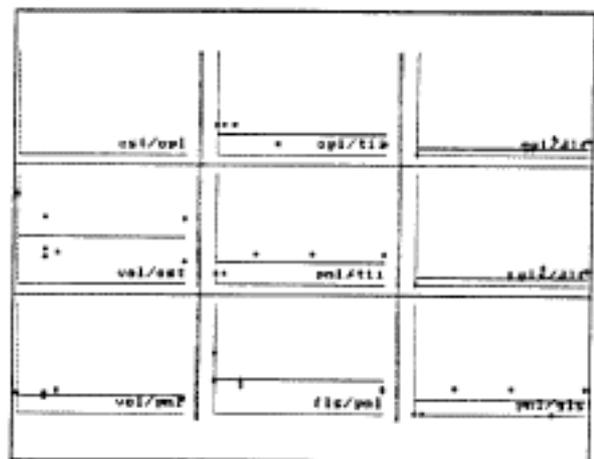

Fig.13 Evaluation screen 1

Fig.14 Evaluation screen 2

The COSMOS output

Now we *will* look at the output produced from the program and the possibilities for use for it. In the first place there is the internal evaluation by the program itself presented on two screens as shown in fig. 13 and 14. This evaluation is based on a bi-variate analysis of the design and the effect variables. Three types of relations have to be distinguished:

- between the design variables to one other:

volume	(m3)	- envelope panels	(m2)
floorspace	(m2)	- envelope panels	(m2)
envelope panels	(m2)	- glass	(m2)

- between the design variables and the effect variables:

volume	(m3) - costs	(Dfl)
envelope panels	(m2) - thermal insulation	(av U)
glass	(m2) - daylight factor	(av DF)

- between the effect variables to one other:

total costs	(Dfl) - envelope costs	(Dfl)
envelope costs	(Dfl) - thermal insulation	(av U)
glazing costs	(Dtl) - daylight factor	(av DF)

On screen one (fig. 13) the user can observe the relation between the absolute values of the above mentioned variables. These values are scaled on the X and Y axis.0n screen two (fig. 14) the user can observe the mean values of the effect variables:

- between the design variables to one other:

volume	with	m2 envelope / m3 volume
floorspace	with	m2 envelope / m2 floorspace
envelope	with	m2 glass / m2 envelope

- between design variables and effects:

volume	with	Dfl costs / m3 volume

The layout of screen one and two is as follows:

total Dfl/Dfl envelope	Dfl envelop/thermal insulation	Dfl glass/daylight factor
volume/Dfl	envelope/thermal insulation	m2 glass/daylight factor
volume/envelope	floorspace/envelope	envelope/m2 glass

Those screens can give the user information about the differences between the sections of the design. Especially in screen two, one can observe the position of the effect variables in relation to the mean. In a linked program EVALUATE it is possible to evaluate a set of designs in the same manner, looking for difference and conformity in performance. COSMOS enables a user to directly evaluate one design at the lime, while EVALUATE enables a user to assess the relations between different design solutions.

In addition to this evaluation on screen, the computed data for each separate section are available to the user as hard copy. Table 1 and 2 refer to a summary of the COSMOS and ELAN output of the example HOUSE1. Option 1 refers to the default output of the example, while option 2 and 3 refer to a modified glazing percentage of the envelop. The distinction between option 2 and 3 rest on different types of glass, single glazing in option 2 and double glazing in option 3.

At the end of COSMOS a menu is presented as shown in fig.15, to prepare data for linked programs; so far the options < 1 > ACAD and <2> ELAN are operational.

OUTPUT MENU:

<1> Make ACAD-files
<2> Make ELAN-files
<*> Make acoustics-files
<*> Make construction-files
<5> Define building material
<6> Resume project
<7> Stop COSMOS
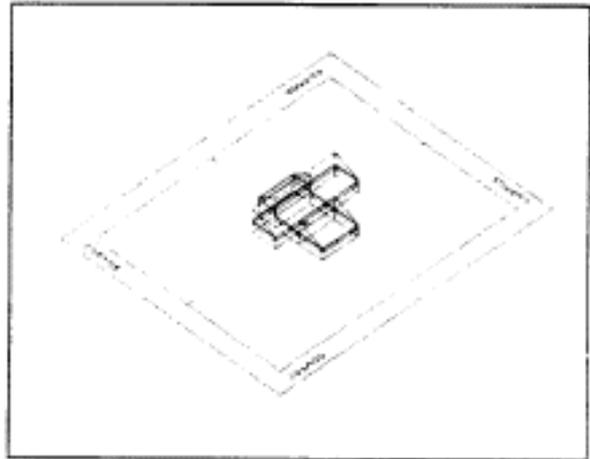
Option ?

Fig.15 Output options menu

Fig.16 Isometric projection

AutoCAD: It is possible to import the COSMOS geometry in the AutoCAD [Autodesk Inc., 1986] program by means of DXF-files. For the user there are three different COSMOS applications at hand:

- COSACAD to look at the isometric projections of the design and make hard copy of them as is shown in fig. 16.

- COSMODEL to make a plot of a scaled cut-out of the COSMOS geometry as is shown in fig. 17 and 18, to give the user without too many problems a paper model of the plan. It can be used for presentation purposes but also to study shape performance in a model environment or study sun and shade in conjunction with a sundial.

- DAAC which consist of two parts. The first part, to bring in more detail in the design sketch on the level of spaces by means of positioning interior walls. doors and openings. This additional geometric information can he read back by COSMOS and processed again to build a more accurate database for evaluation. So even in this stage the user continues to work in a cyclic way to refine the design. The second part, to produce detailed drawings of the floorplans of the design by means of a architectural library. In this phase of the design process there is no evaluation ore whatever calculation involved any more. The output is intended as the designers final draft of his original sketch at the start of the design developing process. To make this draft a hundred per cent preliminary design, all the possibilities of AutoCAD can be used to produce the usual scaled drawings.
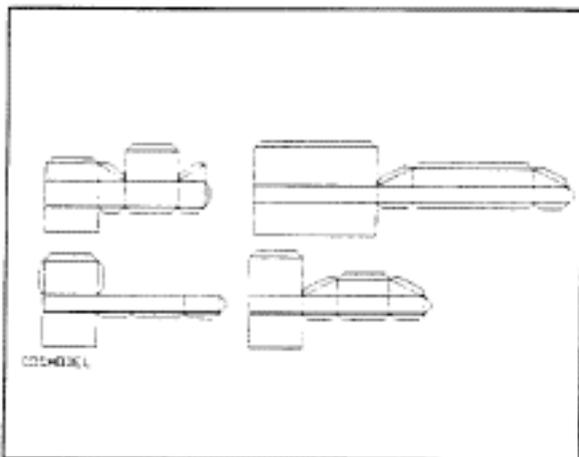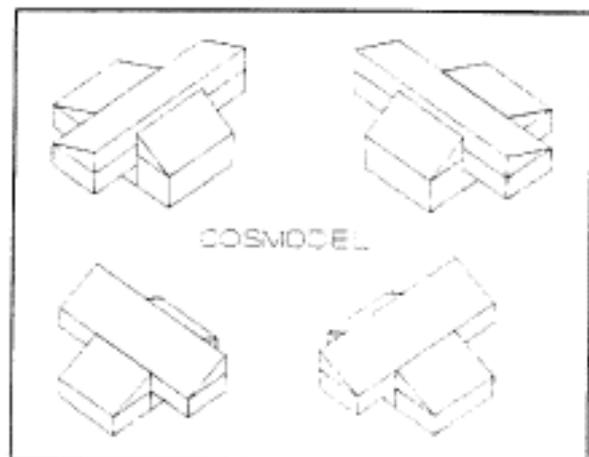
Fig.17 Cut-out of design
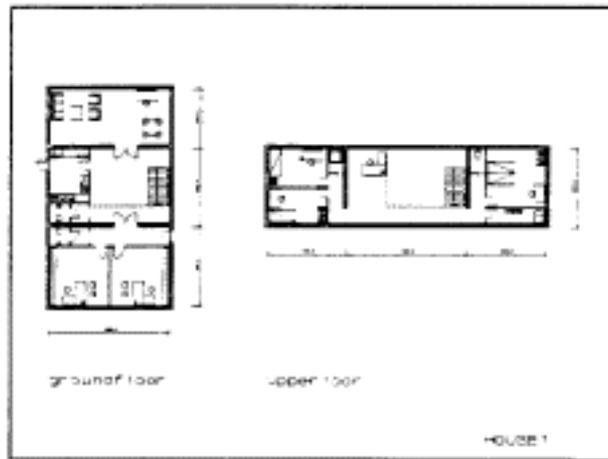
Fig.18 Paper model of design

Fig.19 DAAC: detailed floorplans

ELAN:

The program ELAN [de Wit and Driessen, 19881 is a computer model for building energy design, which is able to import a set of data from COSMOS and perform dynamic calculations about the energy consumption of the design. ELAN is a simplified thermal network model, developed for the assessment of thermal comfort and energy consumption for heating and cooling of a building. The model has the flexibility of large models concerning geometry, number of zones, occupancy pattern. ventilation and weather data. By the use of this program the user is provided with advanced information of the energy performance of the design in question.

In summary, the output of ELAN can he seen in table 2. The glazing differentiation of HOUSE I as shown in the COSMOS output of table 1 is also reflected in the example of ELAN output. In this case it is self-evident that if you compare option 2 and 3 of both output tables, you can observe that an initial investment in double glazing moderates the energy consumption dramatically. In a next step the user may be look for a balance between building costs and the glazing of the exterior walls of the plan, so the user will go back to COSMOS and modify the design variables. In this manner an energy conscious design becomes possible in a relatively quick way at the very early phase of design.

Table 1   Summary of COSMOS output.

Panel costs	Option 1		Option 2		Option3	
	m²	Dfl	m²	Dfl	m²	Dfl
Outerwall	347,6	48668,00	364,0	50967,00	64,0	50967,00
Separation	162,0	32562,00	162,0	32562,00	162,0	32562,00
Groundfloor	148,5	6683,00	148,5	6683,00	148,0	6683,00
Upperfloors	346,5	32225,00	346,5	32225,00	346,5	32225,00
Roofconstr.	283,5	15026,00	283,5	15026,00	283,5	15026,00
Windows/glass	115,9	20293,00	99,5	9129,00	99,5	12610,00

Options:

1 The default values.
2 The modified glass percentage with single glazing.
3 The modified glass percentage with double glazing.

Table 2   Summary of ELAN output.

	Option 1	Option 2	Option3
Insulation:			
It	8,37	7,39	11,42
Av U	,90	,96	,70
Total envelop	1028,41	1028,41	1028,41
Total volume	1215,00	1215,00	1215,00
Ratio env/vol	,85	,85	,85
Energy:			
Consumption kWh	71056,48	64850,00	51622,00
Consumption/m^3	58,00	53,00	42,00

Options:

1 The default values. *2* The modified glass percentage with
single glazing. 3 The modified glass percentage with
double glazing.

Conclusions

There has always been a certain tendency to attack design problems in a sequential order: idea - design -calculation of effects. Generally it is difficult to understand the interaction between design characteristics and building physics. So it is difficult to fully understand the important aspects of a design when it is in progress. To make the design process more explicit, an integration of knowledge about the form and the outcome of physical effects is desirable. To solve the problems connected to the explanation of the design process, a computer program can do the job by combining the diverse expertise of the design and building process. For this reason it is helpful in education as well as in practice for the designer to have a more or less simultaneous design and evaluation tool at his disposal. In the first stage of the design process a similar design tool is especially useful because of the large pay-off contribution possible. It is possible to start from scratch and develop a building design in a for a designer familiar way by means of graphic input. Evaluation of the outcome of the design input is instantly possible within the COSMOS program and in a more detailed way by the use of linked programs.

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